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Ultrafiltration of Oil-in-Water Emulsions with a Dynamic Nylon–Polystyrene Membrane

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Abstract—Dynamic nylon–polystyrene membranes with polystyrene contents of 2.6 and 4.1 wt % have been obtained by applying polystyrene with a particle size of 142–452 nm onto the surface of a nylon membrane with a pore size of 0.45 μm. The deposition of polystyrene onto the surface of the nylon membrane was indirectly confirmed by Fourier-transform IR spectroscopy and probe microscopy. The contact angle of distilled water on the membrane has been found to increase from 44.5° to 106.2° as a result of the deposition of polystyrene particles onto the surface of the initial membrane. The specific productivity of the initial and modified membranes with respect to distilled water and a water–oil emulsion was determined. It has been found that the membrane modification leads to an increase in the degree of removal of petroleum products from an oil-in-water emulsion by 62%; the size of particles separated by the membrane after modification decreased from 450 to 151 nm. It has also been revealed that the specific productivity of the nylon–polystyrene membrane and the original nylon membrane is restored to 98 and 90% of the initial values, respectively, by regeneration.

Keywords: emulsion, ultrafiltration, dynamic membranes, nylon, polystyrene

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INTRODUCTION

As a result of production activity in different branches of industry, wastewaters containing different pollutants are formed depending on the line of activity. Oil-in-water emulsions (OWEs) formed in different branches of industry, such as metalworking, machine building, and petroleum chemistry, which should be separated into hydrocarbon and aqueous phases, present a special problem [1–4]. Standard OWE treatment methods, such as settling, coalescence, centrifugation, flocculation, and coagulation, do not exhibit a high degree of purification efficiency, and the purified water does not meet regulatory requirements imposed on liquid waste discharges released into a sewage system and/or treatment facilities.

Membrane methods such as microfiltration and ultrafiltration are used as promising currently available methods for the separation of OWEs in different branches of industry [1, 2, 5–8]. Highly selective polymer membranes are frequently used in emulsion separation processes. The disadvantages of polymer membranes in ultrafiltration processes for the separation of OWEs are low permeability, a decrease in specific productivity due to the formation of a gel layer on membrane surfaces, insufficient mechanical strength, and high operating pressures. A line for the elimination of the above disadvantages includes the use of dynamic membranes, in which a high degree of separation is ensured by the formation of a thin layer of colloidal particles formed on the surface of a substrate layer and in membrane pores due to the filtration of liquid containing separated components through membranes [9]. Colloidal particles, neutral organic polymers, and organic and inorganic polyelectrolytes are suitable for the formation of dynamic membranes. Dynamic membranes can be prepared on the porous substrate layers of microfiltration and ultrafiltration membranes of various materials (porous metals, ceramics, and polymer films) with pore sizes from 0.01 to 5 μm [10, 11].

A dynamic layer on the surface and in the pores of a microfiltration membrane shifts filtration properties toward ultrafiltration, which makes it possible to more effectively extract organic compounds. The fact that regeneration at increased backwashing rates can be performed for destroying the dynamic layer upon the formation of a gel layer on the surface of the membranes is an advantage of dynamic membranes; this makes it possible to restore the initial characteristics of the membrane, but the repeated regeneration of this